AN ARCHITECTURE FOR INTEGRATED REGIONAL HEALTH TELEMATICS NETWORKS

D. G. Katehakis[1], M. Tsiknakis[1], S. C. Orphanoudakis[1, 2]
[1]Center of Medical Informatics and Health Telematics Applications (CMI-HTA), Institute of Computer Science (ICS), Foundation for Research and Technology – Hellas (FORTH), E-mail: {katehaki, tsiknaki, orphanou}@ics.forth.gr
[2]Department of Computer Science, University of Crete, Heraklion, Crete, Greece

Abstract - **Healthcare is usually delivered within certain organizational boundaries and information produced at each site is managed by isolated autonomous clinical information systems. In some cases point-to-point communication is enabled, facilitating the exchange of information. In contrast, integrated regional health telematics networks enable accessibility to information and services without visible organizational boundaries, to provide decentralized healthcare through integrated services for seamless and personalized information delivery. This has the advantage that enables informed citizens to have an impact on the healthcare system and to be more concerned and care for their own health. The current vision comprises affordable access to healthcare resources and services for all citizens, thus making medical expertise a shared resource wherever and whenever needed. Important areas in which information society technologies are likely to have a significant impact include those of pre-hospital health emergencies, remote monitoring of patients with chronic conditions, and medical collaboration through sharing of health-related information resources. Accessibility to these and other media-rich, user-oriented services, in the context of the emerging global information society, will be supported by a healthcare information infrastructure, which can achieve effective horizontal integration of networked information sources.**

Keywords **– Healthcare Information Infrastructure, Regional Health Telematics Networks, Component-based Architecture**

I. INTRODUCTION

The medical domain is extremely dynamic, consisting of numerous physically disparate information sources over a heterogeneous infrastructure. The user-needs are diverse and no pre-determined clinical processes exist. In addition huge amounts of multimedia data are produced daily, that are managed by autonomous clinical information systems, provided and supported by multiple vendors. What the healthcare domain requires is the existence of specialized clinical information systems, dedicated to individual functional areas, and the provision of secure services of a certain quality level to support efficiently decision making wherever it is needed. The effective management of the huge volumes of multimedia data that are produced daily, together with the effective management of medical acts and processes are required as well. Scalability and modularity is another requirement, as well as multi-vendor support that can be made feasible by assuring interoperability among applications and services. This is the only way to provide best value for money, and to make services affordable even for small hospitals.

The main challenge today has to do with the development of the appropriate Healthcare Information Infrastructure (HII) that will be in a position to support all the requirements of the healthcare domain. This necessitates the existence of an underlying, reference architecture to support the HII and to enable integrated support to the clinical, organizational, and managerial activities of the healthcare organization as a whole [1]. Ideally a single user interface for access to the global healthcare-related information space is also needed, as part of an environment for the provision of advanced health telematics services over integrated regional health telematics networks, and the provision of extra services through trans-regional networks.

The creation of the HII is driven, among other factors, by the need for:

1) data on outcomes of medical cases that will enable effective choices and compensation of providers,

2) automation of mundane tasks to place the focus on patient needs rather than paperwork,

3) empowerment of consumers to become more actively involved in their own healthcare,

4) flexible remote access to relevant information in order to ensure continuity of care,

5) continuous process improvement through integrated and distributed information technology.

For an HII to be developed, good knowledge and understanding of the involved domain is needed. Therefore it requires a thorough user requirements analysis together with the solution of all medico-legal issues that are of great importance and hard to deal with. This involves the definition of the corresponding and necessary reference architecture, which defines the framework for the integration of heterogeneous, autonomous, distributed information systems that are networked, together with the development of necessary network infrastructure to support the services. In addition definition of public and stable interfaces and protocols is also required together with the provision of the appropriate middleware and user-oriented services.

The new paradigm provides that informed-citizens care for their own health and, together with other cooperating stakeholders (who may also be responsible for the continuity of health services within a region) have an impact on the operation of the healthcare system as a whole. In this context, decentralized healthcare can be supported by integrated services for seamless and personalized information delivery, while services and information must be accessible without visible organizational boundaries.

The telematic services, which are typically delivered within a regional health telematics network, may be classified into five basic classes: *collaboration*, *resource*, *educational*, *integrated electronic health record (I-EHR)*, and *added value* services [2]. These classes of telematic services are applicable to all four healthcare application areas of home, primary, hospital, and emergency care.

Report Documentation Page

Report Date	Report Type	Dates Covered (from... to)
25 Oct 2001	N/A	-

Title and Subtitle An Architecture for Integrated Regional Health Telematics Networks	**Contract Number**
	Grant Number
	Program Element Number
Author(s)	**Project Number**
	Task Number
	Work Unit Number
Performing Organization Name(s) and Address(es) Center of Medical Informatics and Health Telematics Applications (CMI-HTA) Institute of Computer Science (ICS), Foundation for Research and Technology - Hellas (FORTH) Greece	**Performing Organization Report Number**
Sponsoring/Monitoring Agency Name(s) and Address(es) US Army Research, Development & Standardization Group (UK) PSC 803 Box 15 FPO AE 09499-1500	**Sponsor/Monitor's Acronym(s)**
	Sponsor/Monitor's Report Number(s)

Distribution/Availability Statement
Approved for public release, distribution unlimited

Supplementary Notes
Papers from 23rd Annual International Conference of the IEEE Engineering in Medicine and Biology Society, October 25-28, 2001, held in Istanbul, Turkey. See also ADM001351 for entire conference on cd-rom., The original document contains color images.

Abstract

Subject Terms

Report Classification unclassified	**Classification of this page** unclassified
Classification of Abstract unclassified	**Limitation of Abstract** UU

Number of Pages
4

1) *Collaboration services* allow for the secure exchange of information related to certain cases or incidents.

2) *Resource services* provide information about the availability of healthcare resources, like e.g. physicians belonging to certain specialties, hospitals on duty, or availability of services.

3) *Educational services* raise public awareness and facilitate distance learning through the use of telematics.

4) *I-EHR services* provide the environment to support the integration of all the fragments of information that concern a single person, are associated with his/ her personal healthcare and are maintained by a number of diverse and geographically distributed clinical information systems.

5) Finally, *added-value services* (e.g. image processing, information indexing, data pre-fetching, etc.) provide specialized support to healthcare professionals.

II. Methodology

Different groups of people have different conceptions about systems and services offered to them. All of them (including doctors, technicians, engineers, decision makers, businessmen, etc.) have different requirements and needs. What is important is that, if involved, all of them can contribute significantly in the development process of a system that afterwards will be used to promote the needs and goals of everyone. For the case of the health domain, the strategic objective is to ensure that citizens can be confident that the healthcare professionals caring for them have reliable and rapid access, 24 hours a day, to the relevant personal information necessary to support their care. This paper concentrates exactly at the point where the external functionalities of systems and services are separated from the underlying technological infrastructure.

Basic principles to be followed in providing effective solutions to integrated health telematics services networks include:

1) The promotion of interoperability among multi-vendor applications and services.

2) The use of open standards, made available to the customer.

3) The provision of high quality services, useful not only to end-users but to the society as well.

4) The implementation of modular architectures to be scaleable, secure, effective, and affordable – even for small hospitals.

An important consideration has to do with the commitment to evolve from the currently available infrastructure, while adding new capabilities as soon as they become available and can become part of the local culture [3].

As software systems grow larger, healthcare delivery systems become more complex and more interdependent. Today software component technology has emerged as a key enabling technology. A software component is a unit of third-party composition, sufficiently self-contained, independent of deployment that interacts with its environment through well-defined interfaces and no persistent state [4].

There are two engineering drivers in the development of a component-based system:

1) *Re-use*: The ability to re-use existing components to create a more complex system

2) *Evolution*: A highly component-based system is easier to maintain. The changes will be localized, with little or no effect on the remaining components.

The three-tier approach [5], which heavily depends on the existence of both generic and healthcare specific middleware services or components imposes a level of common design that varies according to the actual composition of the platform. The higher the number of common services presents in the platform the more restrictions there are in the design of the applications. On the other hand, common services also make it quicker and easier to design and implement applications as they utilize common services that already exist.

In order to achieve the goals set, a reference architecture is required to provide the basic framework for the development of advance health telematics applications described in terms of basic component functionalities and their interfaces. Any reference architecture may correspond to several alternative execution architectures. The underlying technology is called distributed object technology, and three are the basic computing infrastructures that today provide for transparent inter-process communication:

1) *Microsoft's Distributed Component Object Model* (DCOM) is an integration architecture that targets the homogeneous Windows environment (personal computer) and permits interaction between objects executing on separate hosts in a network [6].

2) *Sun's Java Remote Method Invocation* (RMI) is based on the execution environment of Java to support network computers. In addition, Java 2 Platform, Enterprise Edition (J2EE), allows for the building of distributed object applications using RMI over the Internet Inter-ORB Protocol (IIOP) [7].

3) The *Object Management Group's (OMG) Common Object Request Broker Architecture (CORBA)* supports object distribution across heterogeneous environments, based on common interfaces that become standards through their adoption by the software industry [8].

No matter what is the technology of choice, the adoption of a component approach in server applications, saves a lot of time in maintenance and increases the potential for future improvements.

In this context, a set of middleware enabling services are identifiable: *collaboration services* to enable general practitioners and medical experts to share patient-related information, *patient identification services* to enable the association of distributed patient record segments to a master patient index, *authentication services* to manage the roles and corresponding access rights of users, *encryption services* for the secure communication of sensitive personal information, *auditing services* for recording all interactions between middleware services and/ or end-user applications, *resource location services* for identifying available healthcare-related agents (like e.g. organizations, devices, software, etc.) and the means for accessing them, *I-EHR indexing services* to enable indexing primary health information, *primary health*

information access services for directly accessing primary health information, *user profile services* to enable personalized delivery of information, and finally *terminology services* for both concept and internal semantics mapping.

III. Application domains

The development of HYGEIAnet (see Fig. 1), which is the integrated health telematics network of Crete focuses towards providing an integrated environment for healthcare delivery and medical training across the island [9]. HYGEIAnet takes advantage of the increasing capacity of terrestrial and mobile communication networks and the development of advanced telemedicine services to provide every citizen of the island with effective healthcare services and to support remote consultation among healthcare professionals in specialized centers, district and regional hospitals, and other points of care.

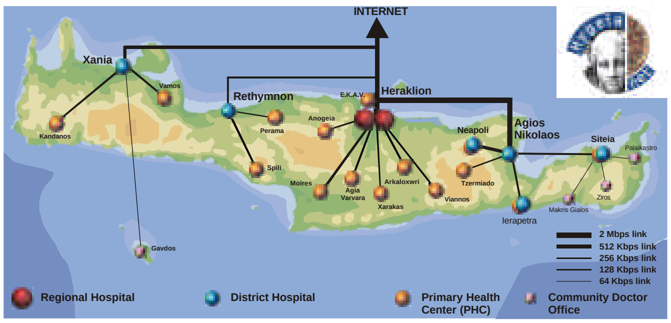

Fig. 1: HYGEIAnet, the Integrated Health Telematics Network of Crete in Greece.

Health telematics involves the use of information processing tools and telecommunications to provide the functional and operational framework that allows computers to transfer medical data to one another. Interoperability among telematic services and standalone applications is critical, since services and applications share data and information. Hence, telematic services need to be part of a collaboration environment that ensures the continuity of care and information sharing, under strict security and authorization policies.

The application layer of the HYGEIAnet reference architecture (Fig. 2) consists of applications, which support user activities in the various areas of an organization. These applications are both information sources and/ or information access points. All applications and services of the application layer make use of their own data model and user-interface.

WebOnCOLL is an example of an underlying enabling infrastructure that supports the secure collaboration between general practitioners and medical experts in Crete [10]. This type of services, bridge the gap created by the physical distance separating the various users, while promoting social interaction and the exchange of vital information.

Another important issue to be handled by the infrastructure has to do with patient identification. It is common that people throughout their lifecycle have several episodes of care that have been handled through numerous healthcare organizations. Today most of those organizations maintain autonomous patient identification codes that have no meaning outside their own identification domains. This poses a problem, since what is missing is the base for the efficient correlation of health records through multiple organizations.

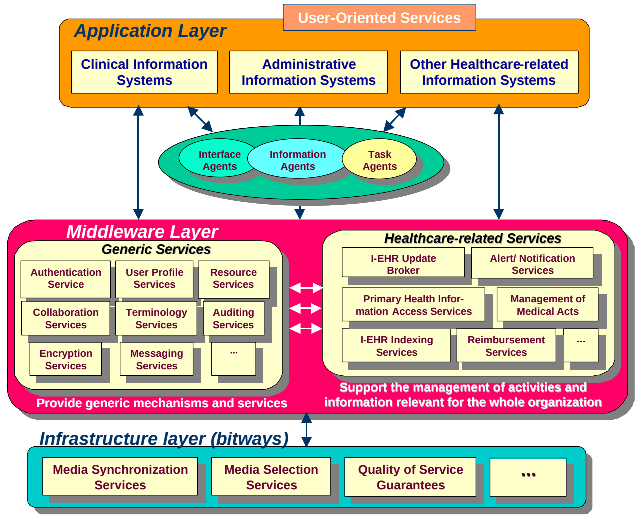

Fig. 2: HYGEIAnet Reference Architecture.

In the region of Crete this has been handled by means of the Patient Clinical Data Directory (PCDD) [11]. The PCDD is a central middleware element of the overall architecture that provides information on the distributed EHR segments maintained by autonomous information systems. It provides the means for both the correlation of patient identification into a single master patient index but also the linking of the I-EHR fragments that belong to an individual.

When dealing with seamless access to information, secure access; together with all the related issues become apparent. Despite the fact that *application security* is mainly concerned with access control and data quality, *communication security* deals with user identification, user authentication, and certification by showing trust to a Trusted Third Party (TTP). Access to detailed information regarding specific healthcare encounters ought be provided subject to role-based authorization privileges and controls.

It is evident that the existence of a trust infrastructure needs to evolve as part of the environment. This way security and confidentiality services can be based on a regional certification authority, which will provide digital certificates to healthcare facilities and human resources.

IV. Discussion

When developed, the components of the HII realize their potential as more of them become available. This is because component-based software development shifts the focus from new software development to the integration of existing components to perform new tasks. At the same time addresses the issues of large-scale system development in the areas of coupling, distribution, and the utilization of multiple platforms.

Whatever the technical architecture or platform is in real life its selection is only part of the solution. The other part of the solution is migration. In most cases, even in health care,

there are already existing applications and an existing infrastructure. The task is to add new applications to this infrastructure or to replace existing ones with new better applications or both. Also it is often desirable to continue to make use of the databases that store valuable data even though the actual applications will be replaced. This is called encapsulation of legacy systems. An implementation strategy or migration path as part of the overall information management and technology strategy is necessary to manage these processes.

There are different reasons why standards are needed in the healthcare domain. One such reason is that standards allow computer documentation to be consistent with paper-based medical records. Another reason is that information sharing (communication) among different actors, for the purpose of addressing an end-user's problem, is facilitated by the existence of standards-based integrated environments. This includes all agreements on data and context that needs to be shared, so that decision support is provided and there is a return on investment. Healthcare domain standards can be distinguished into standards for terminology, data communication, and software component interoperability.

V. Conclusions

In deploying Information and Communication Technologies (ICT) in health care, the following issues need to be considered carefully:

1) ICT is treated as an investment, not cost. This means that it is a strategic resource with the potential of enabling and supporting the enterprise in meeting its goals (strategic objectives)

2) ICT facilitates communication and information management by providing connectivity and making it possible to access information at any time and at any place. The degree of connectivity depends on the willingness of the parties concerned to share processes and their underlying concepts.

3) Access to the HII should be as easy as possible and tailored (or adapted) to the needs of users (citizens, patients and health professionals).

4) The overall ICT infrastructure (HII) needs to be stable, manageable and maintainable

5) The functionality provided by the HII must be such that the users trust it. This comprises in addition to stability and the normal user applications also an implemented privacy and data security policy, which meets not only the requirements of existing legislation but also the expectations of the users. Trust also includes the content and quality of medical knowledge (best practices) contained or accessed through the HII.

When migrating from an existing infrastructure towards a new one, several issues with associated costs have to be considered. The first is these deals with what changes are necessary in the platform for that to be able to support the applications. It may be that the existing infrastructure only uses ad-hoc messaging. Decisions have to be formulated how and when to upgrade the platform itself and whether the expected benefits and savings outweigh the costs involved.

HYGEIAnet has followed so far a top down approach and has identified quite a big number of components. These components, the more they become the more evident their need becomes to realize their potential. The common service approach requires teams that are trained and seasoned in distributed object technology, to efficiently face the challenges of large-scale system design and development, for enabling the creation of the next generation regional networks.

Acknowledgment

The work presented in this paper is funded in part by the European Commission through the PICNIC project (IST-1999-10345).

References

[1] M. Tsiknakis, D.G. Katehakis, S.C. Orphanoudakis, "Information Infrastructure for an Integrated Healthcare Services Network", Information Technology Applications in Biomedicine (ITAB-ITIS 2000), IEEE EMBS 3rd International Conference, Arlington, Virginia, USA, November 9-10, 2000.

[2] D.G. Katehakis, M. Tsiknakis, S.C. Orphanoudakis, Information Society Technologies in Healthcare, in "SOFSEM 2000 - Theory and Practice of Informatics", V. Havlac, K.G. Jeffery, and J. Wiedermann (editors), LNCS, Vol. 1963, pp. 152-172, Springer-Verlag, 2000.

[3] D.G. Katehakis, M. Tsiknakis, S.C. Orphanoudakis: "Enabling Components of HYGEIAnet". Proc. of TEPR 2001, Boston, MA, pp. 146-153, May 8-13, 2001.

[4] C. Szyperski: "Component Software: Beyond Object-Oriented Programming", Addison Wesley Longman Ltd, 1998.

[5] European Pre-standard CEN/ TC251/ WG1/ PT1-013: “Medical Informatics: Healthcare Informa-tion System Architecture” Brussels, CEN, November 1995.

[6] Microsoft Component Object Model, URL: http://www.microsoft.com/com

[7] Java™ 2 Platform, Enterprise Edition, URL: http://java.sun.com/j2ee

[8] Object Management Group, URL: http://www.omg.org

[9] HYGEIAnet, URL: http://www.hygeianet.gr

[10] C.E. Chronaki, D.G. Katehakis, X. Zabulis, M. Tsiknakis, S.C. Orphanoudakis, "WebOnCOLL: Medical Collaboration in Regional Healthcare Networks", IEEE Transactions on Information Technology in Biomedicine, vol. 1(4), 257-269, 1997.

[11] D.G. Katehakis, P. Lelis, E. Karabela, M. Tsiknakis, S.C. Orphanoudakis: "An Environment for the Creation of an Integrated Electronic Health Record in HYGEIAnet, the Regional Health Telematics Network of Crete". Proc. of TEPR 2000, San Francisco, CA, Vol. 1, pp. 89-98, May 9-11, 2000.